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(71) Applicant
Brother Kogyo Kabushiki Kaisha

(Incorporated in Japan)

No 35 Horitadori 9-chome, Mizuho-ku, Nagoya-shi, Aichi, Japan

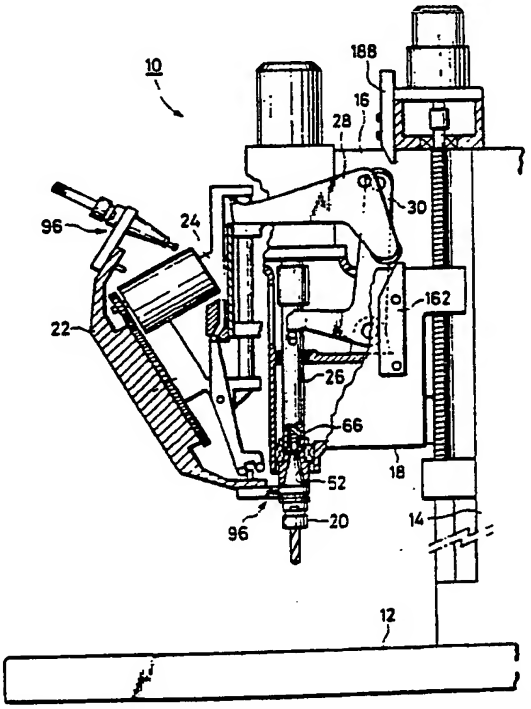
(72) Inventors
Kikuo Watanabe
Mitsuo Kobayashi
Noboru Hirose
Keiichi Sato

(74) Agent and/or Address for Service
Gill Jennings & Every
53-64 Chancery Lane, London, WC2A 1HN, United Kingdom

(54) Machine tool with indexable tool magazine

(57) A machine tool with a vertically reciprocating spindle head 18 has an automatic tool changer including a rotatably indexable tool magazine 24 connected to a frame for the machine tool. Tool holders 96 on the tool magazine 24 are indexable to be aligned selectivley with the spindle axis for direct tool take-up by the spindle head 18. Each holder 96 has tool gripping claws which when in the open position allow passage of the spindle head 18 for machining operations, there, the magazine 14 otherwise rotunlly movable, is prevented from following the spindle head 18.

FIG. 1



At least one drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982

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FIG. 1

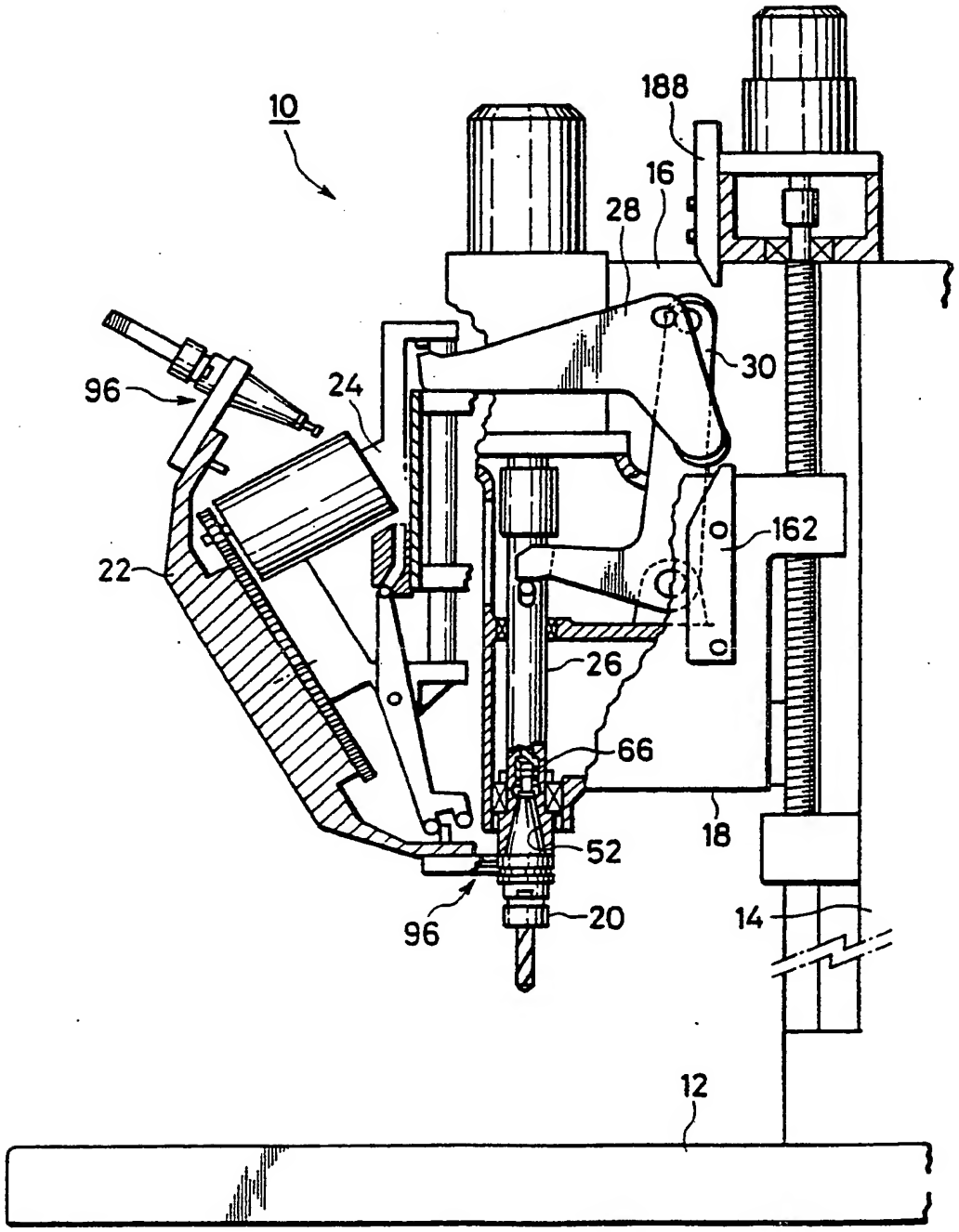
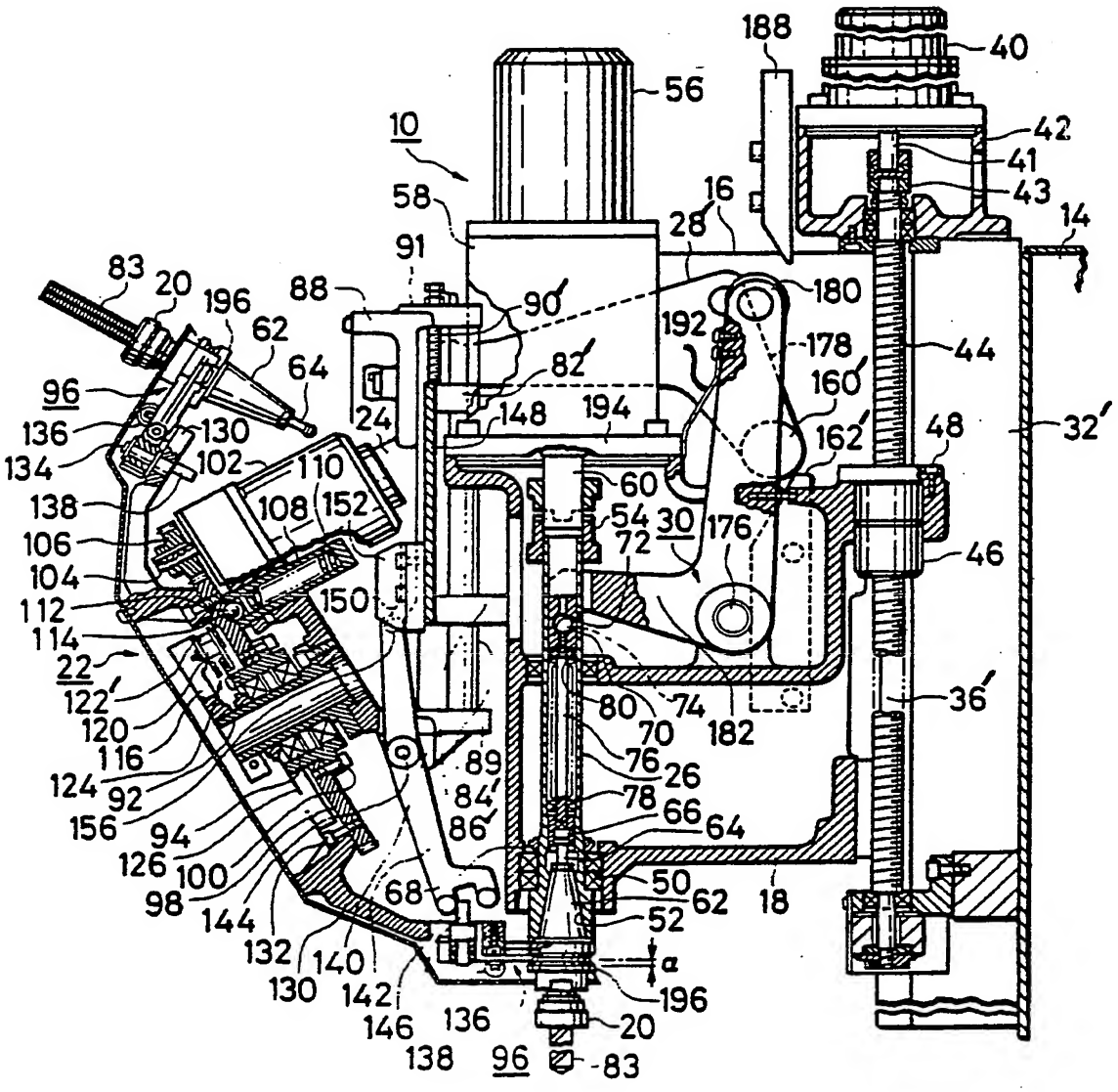


FIG. 2


188
40
56
10
42
41
43
58
16
28
14
91
83
20
196
88
90
180
62
192
178
44
64
82
160
96
24
148
194
162
48
32
136
130
102
110
60
134
108
152
54
30
176
138
72
46
106
104
150
112
114
22
36
122
80
74
70
182
120
116
89
76
26
124
92
84
78
66
64
156
94
86
126
100
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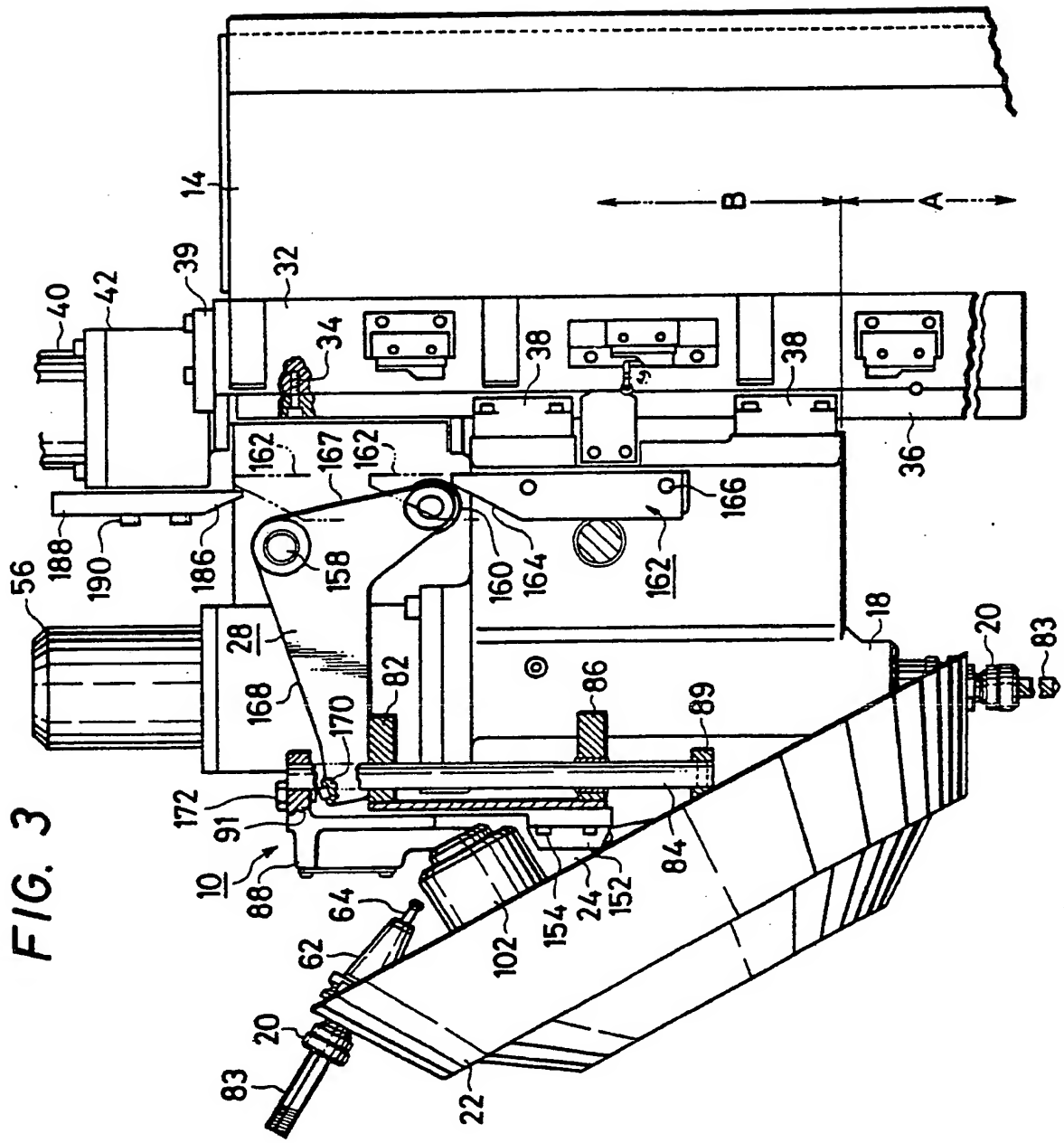
130
142
146
136
138
96
83
20
196
α


14
B
A
39
32
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42
34
38
38
36
162
167
162
166
188
190
186
158
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164
162
56
28
18
20
83
168
82
86
89
170
172
91
10
88
64
62
102
154
24
152
84
20
83
22

FIG. 3

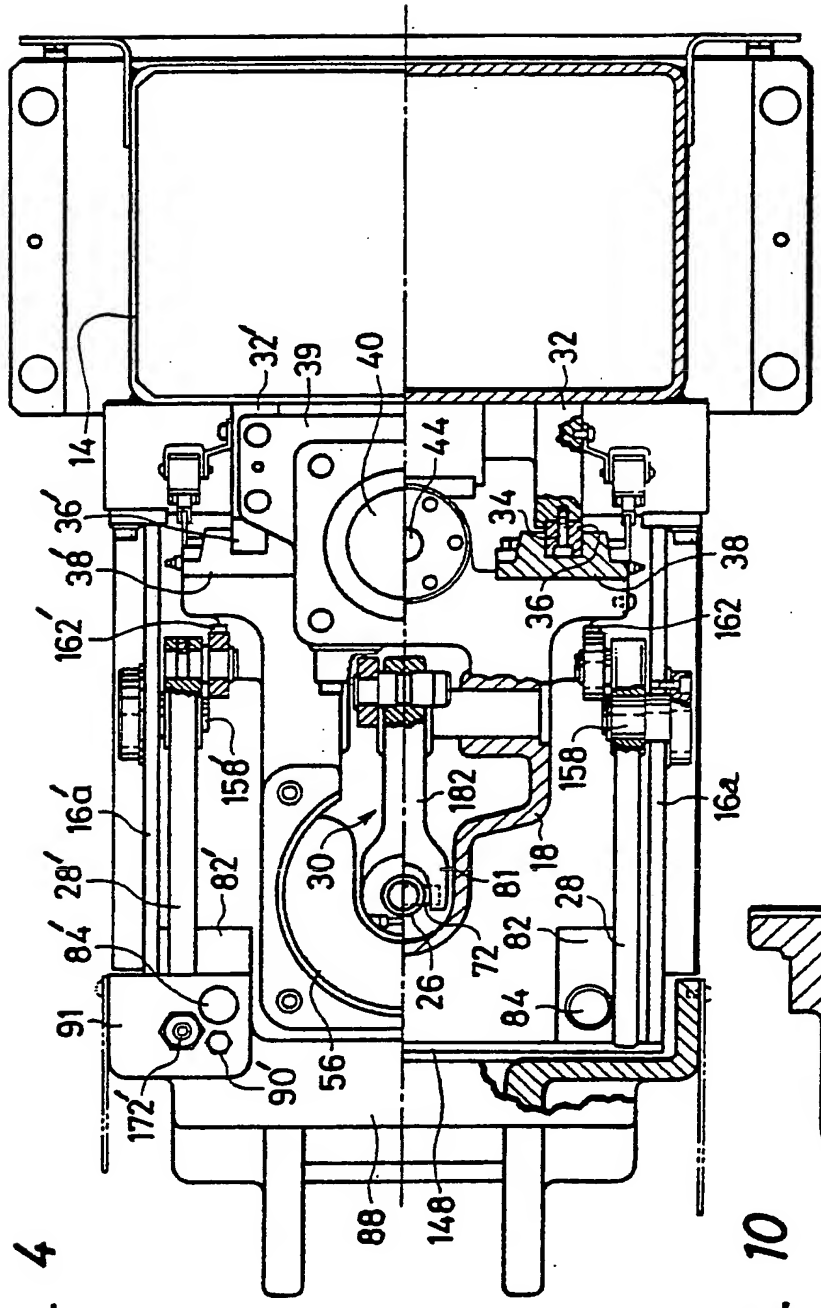

14
32'
39
40
32
44
34
36'
38'
162'
36
38
162
158'
158
16a'
16a
182
30
18
28'
82'
81
28
84'
82
72
26
84
91
90'
56
172'
88
148

FIG. 4

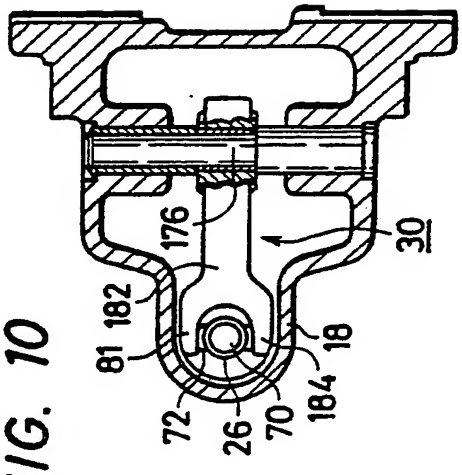

176
30
81
182
18
72
26
70
184

FIG. 10

FIG. 5

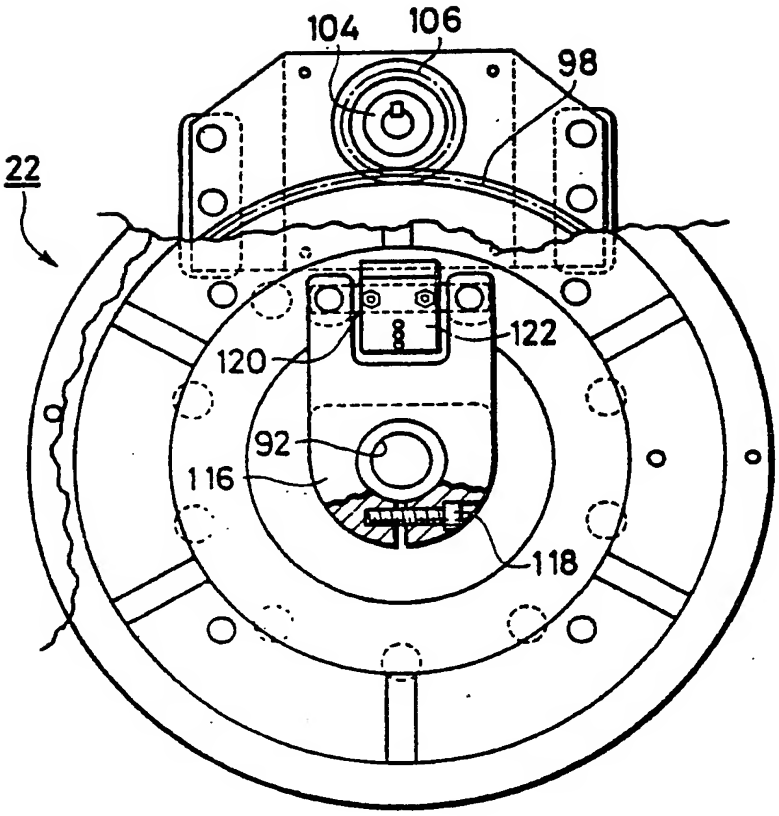


FIG. 6

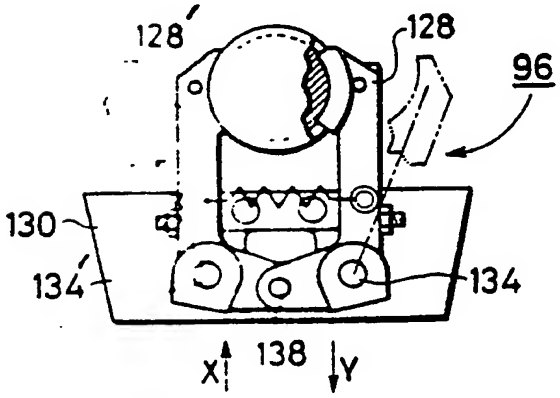


FIG. 7(a)

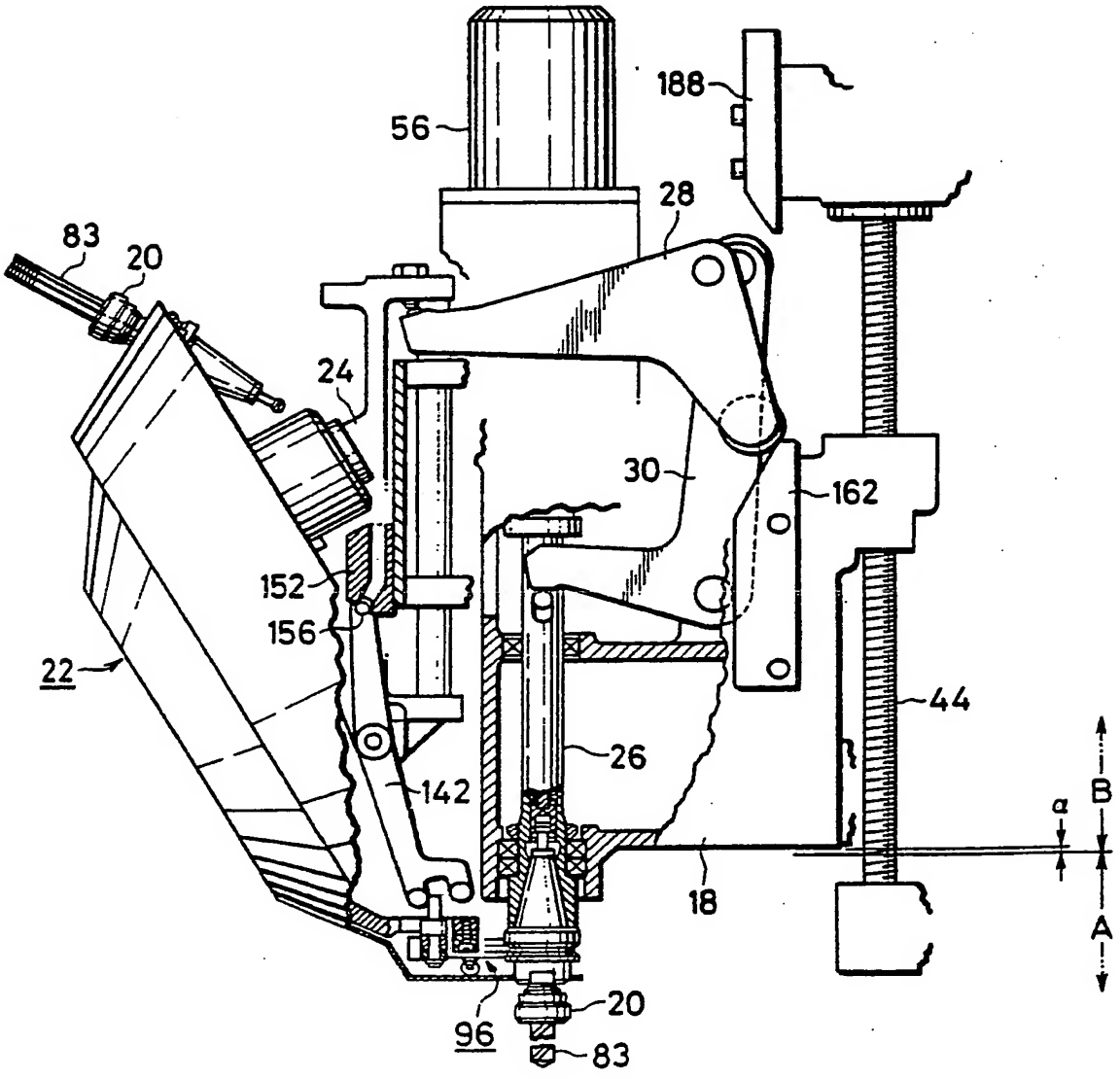


FIG. 7(b)

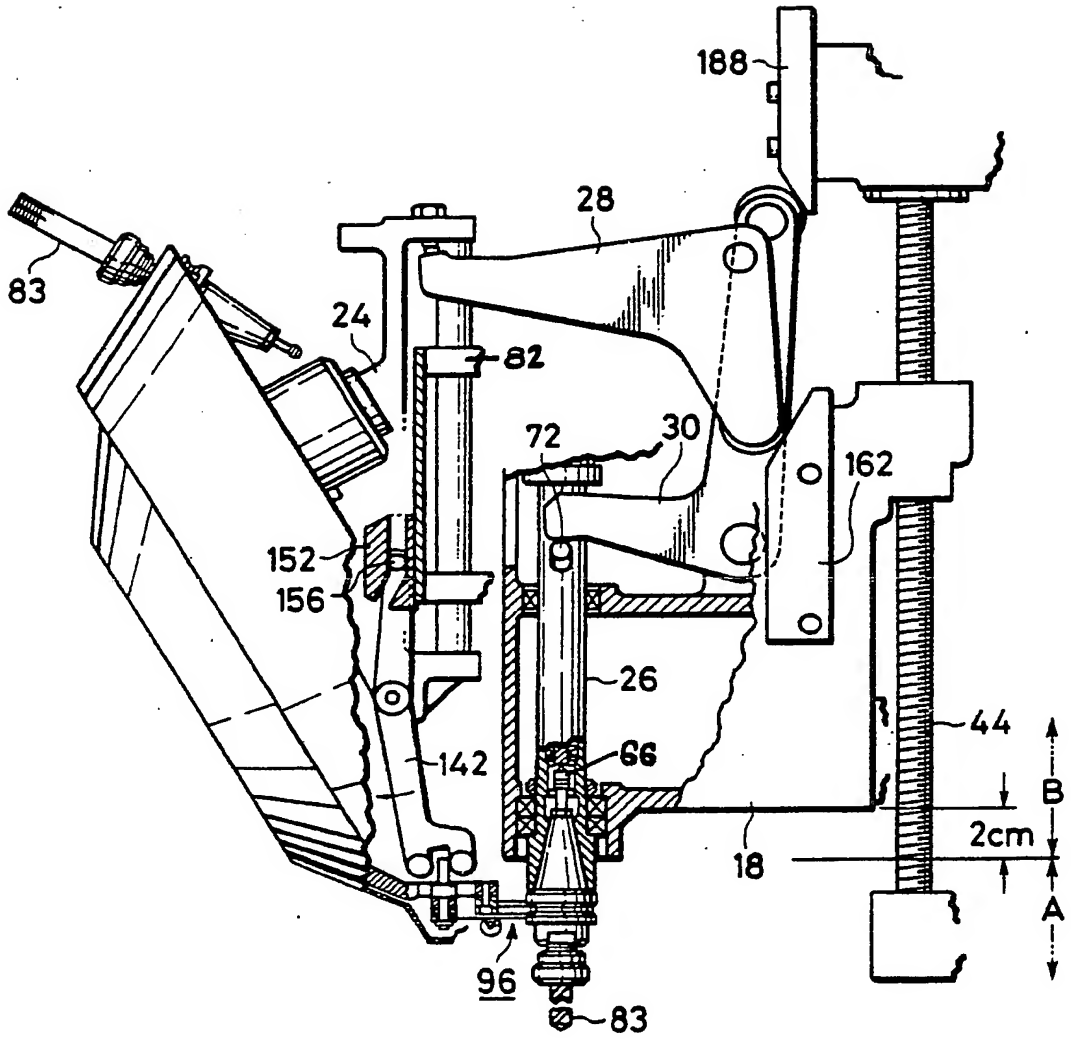


FIG. 7(c)

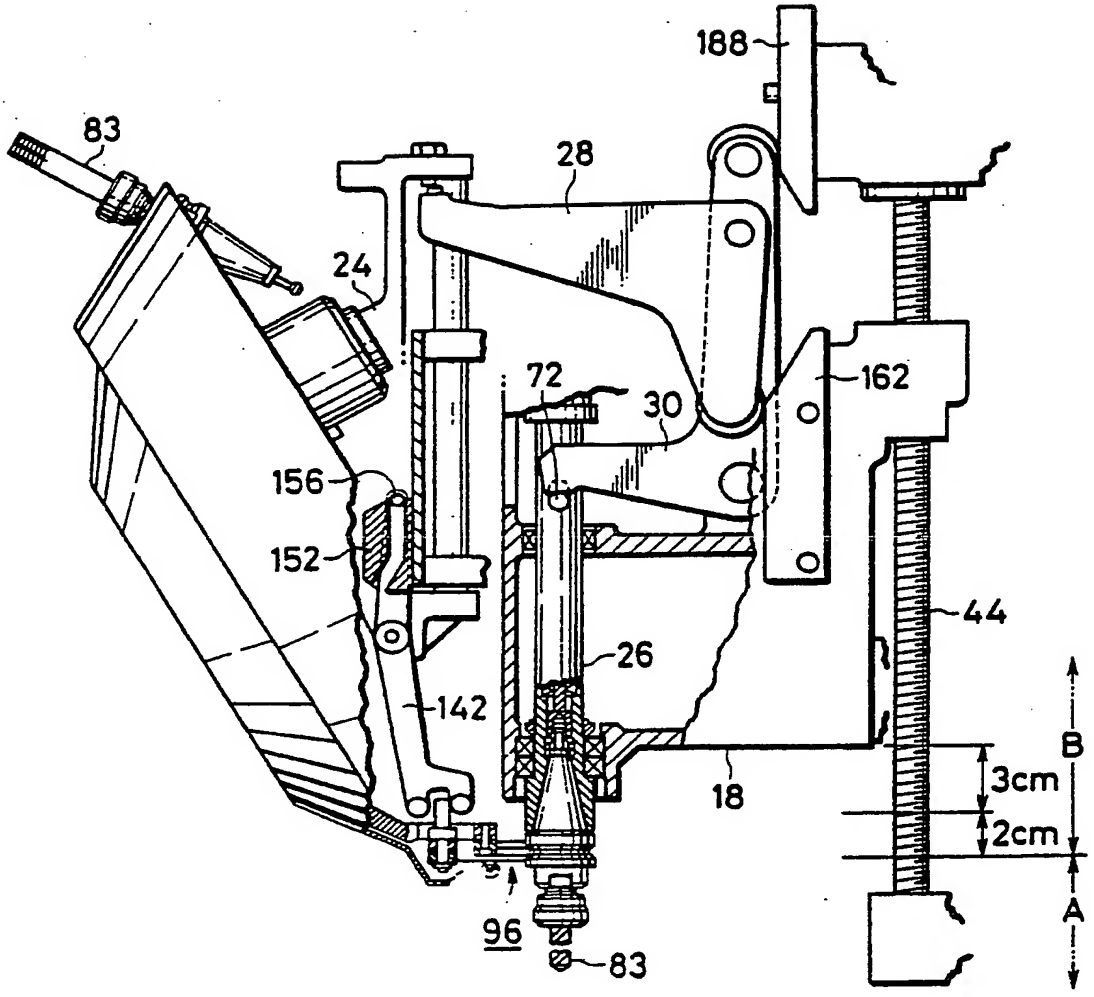


FIG. 7(d)

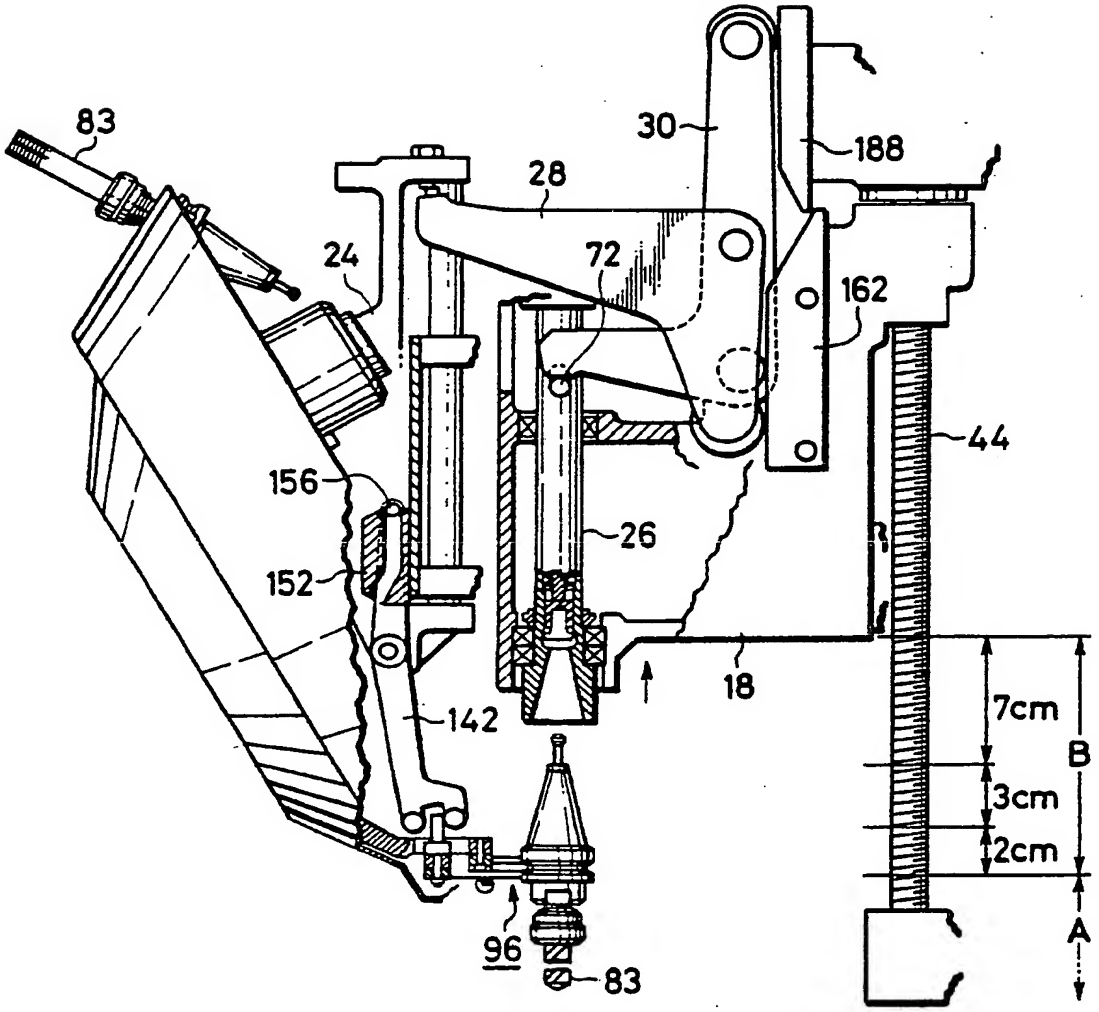


FIG. 8

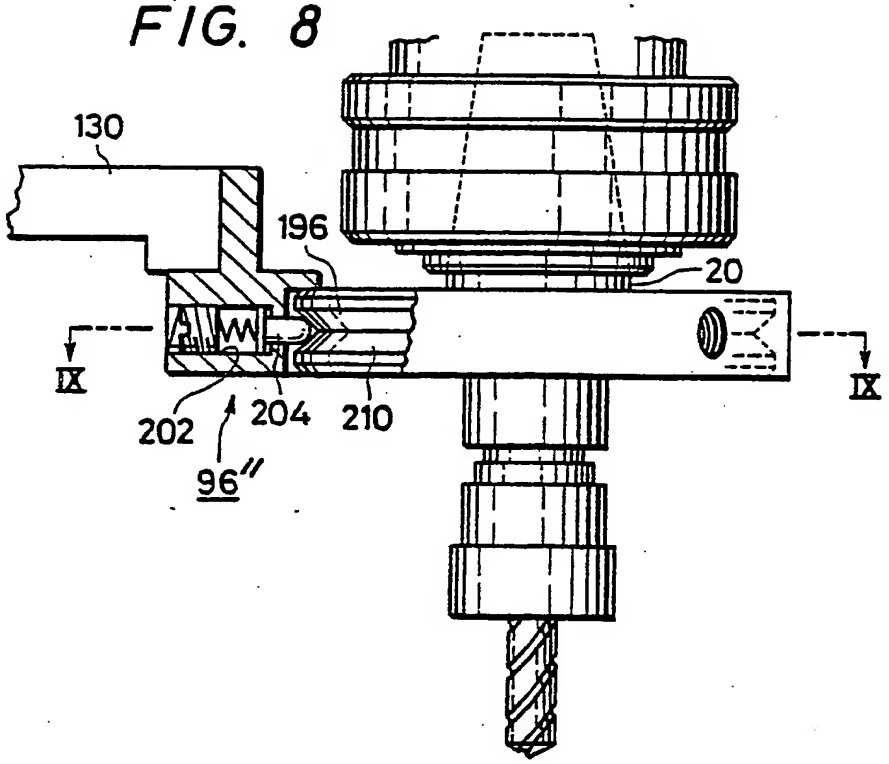
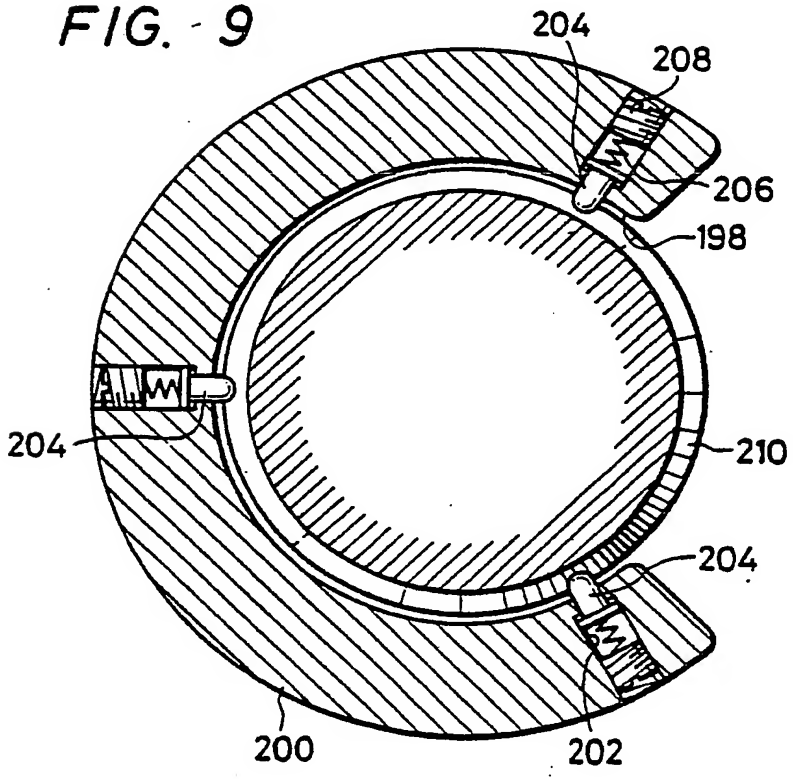

130
196
20
IX
IX
202
204
210
96''

FIG. 9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This invention relates to a machine tool and more particularly to a machine tool equipped with an automatic tool changer (ATC).

In a machine tool, such as a multi-purpose machining centre for threading and cutting holes in workpieces, a number of taps and drills are stored in a predetermined place before machining. Using an ATC, the tool being used can be exchanged with another type of tool or a new one, automatically. Various kinds of ATC have been proposed, and one ATC having a relatively simple construction has been disclosed in Japanese Published Pat. Appln. No. 58-51046. In that ATC, a disc tool magazine with many tools radially arranged is rotatably mounted on a main spindle and reciprocates with the main spindle during non-tool changing machining operations. The tool magazine can slide relative to the main spindle head only when the main spindle head reaches an automatic tool changing region which is located directly above its machining region, the machining region being where the main spindle head normally moves up and down for machining purposes. In a machine tool with this type of ATC, the main spindle head first is slid upwardly relative to the tool magazine to extract the used tool from the toe of the main spindle. Subsequently, the tool magazine is rotatably indexed to allow a replacement tool to move beneath the main spindle with their respective axes aligned. The main spindle then slides downward to capture the new tool.

Serious disadvantages can exist in a machine tool having an ATC of such a construction. Because the tool magazine moves together with the main spindle head during machining operations, tools mounted on the tool magazine

and extending in the radial direction can interfere with the workpiece being machined, depending on the shape of the workpiece. Another disadvantage is that a machine tool with such an ATC can be quite complicated in construction, be prone to develop trouble, and be relatively expensive.

In accordance with one aspect of the present invention, however, a machine tool comprises: a frame; a main spindle head rotatably supporting a main spindle, said main spindle head being reciprocable relative to said frame in the axial direction of said main spindle; a tool holding member installed in a tool mount at one end of said main spindle; and automatic means for changing a tool held in said tool holding member during a "double action" tool-changing movement of said main spindle head, said automatic means including:

a. a tool support carried on said frame and movable in the axial direction of said main spindle independently of said main spindle;

b. a tool magazine rotatably supported on said tool support and having a plurality of tool holders each capable of detachably holding said tool, and spaced about the periphery of said tool magazine, said tool magazine being capable of indexing a selected tool holder into and out of axial alignment with said main spindle;

c. first cam-and-crank means interconnecting said main spindle head, said frame and said tool support for moving said tool support together with said main spindle head a predetermined distance during the "double action" movement of said main spindle head relative to said frame, said tool held in said tool holding member also being engaged and held by one of said tool holders of said tool magazine during travel in said predetermined distance;

d. second cam-and-crank means interconnecting said main spindle head and said frame for causing said tool holding member to release said tool during a preselected portion of said "double action" movement, and

e. means for preventing movement of said tool support below a fixed axial location, said main spindle head being movable below said fixed axial location for performing machining operations.

In accordance with another aspect of the present invention, a method of automatically changing a tool held in a tool holding member of a machine tool spindle head, the spindle head being axially reciprocably movable relative to a machine tool frame, comprises the steps of:

a. providing a tool support, with associated tool holders, carried on the frame and axially movable with respect thereto;

b. elevating the spindle head a first distance, said first elevating step including the steps of simultaneously;

(i) raising the tool support along with the spindle head over the first distance, and

(ii) engaging and holding the tool with one of the tool holders;

c. elevating the spindle head a second distance beyond the first distance, said second elevating step including the steps of simultaneously;

(i) raising the tool support along with the spindle head over the second distance, and

(ii) disengaging the tool from the tool holding member while continuing to hold the tool with the tool holder;

d. elevating the spindle head a third distance beyond the second distance without raising the tool support, to separate the tool from the spindle head;

e. replacing the tool with a replacement tool, said

replacing step including performing steps b, c and d in reverse order to mount the replacement tool in the tool holding member; and

f. stopping downward movement of the tool support at a position above a machining region, the spindle head being movable into the machining region.

A machine tool and a method, in accordance with the present invention, will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram illustrating an arrangement of principal members constituting a machine tool embodying the present invention;

Figure 2 is a vertical section illustrating in detail the internal structure of the machine tool of Figure 1;

Figure 3 is a partially cutaway side view of the machine tool of Figure 1;

Figure 4 is a partial top view of Figure 2 with a partial cross section as an aid for the observation of internal structure;

Figure 5 is a schematic diagram of the tool magazine used in the Figure 1 embodiment;

Figure 6 is a schematic diagram of the tool holder used in the Figure 1 embodiment;

Figures 7(a)-(d) are diagrams illustrating the method of operation of the machine tool of Figure 1;

Figure 8 is a schematic diagram of an alternative tool holder for use in the Figure 1 embodiment;

Figure 9 is a cross sectional view of the tool holder in Figure 8 taken on line IX-IX; and

Figure 10 is a cross sectional view illustrating a state of operation of the machine in Figure 1 wherein a forked portion provided at the toe of a second crank is

positioned above a pin horizontally projected from the main spindle.

The construction of a machine tool 10 embodying the present invention is shown schematically in Figure 1, wherein a main spindle head 18 rotatably supporting a main spindle 26 with a tool mount 52 installed at its toe end, is vertically movably supported by a frame 16 so that a workpiece may be machined as desired. The tool mount 52 is equipped with a tool holding member 66 for holding a tool 20, the tool being axially detachable therefrom. A tool magazine 22 supplied with a plurality of radially arranged tool holders 96 is rotatably supported by a tool support 24, and the tool support 24 is supported by the frame 16 for vertically upward movement independent of the main spindle head 18. There is also a first cam-and-crank mechanism 162, 28 for causing the tool 20 installed at the toe of the main spindle 26 to be relatively held or released by the tool holder 96, and a second cam-and-crank mechanism 188, 30 for causing the tool 20 to be released and pulled out of the main spindle 26.

Referring to Figures 2-6, the principal construction of the machine tool embodying the present invention will now be described in greater detail. The rigid frame 16, formed as a box-like hollow casing, is horizontally fixed to the front face of a column 14 arranged uprightly on a base 12 of the machine tool 10. The main spindle head 18, rotatably supporting the main spindle 26, is vertically movably mounted in the frame 16. As shown in Figures 3 and 4, identical guide rails 36, 36' are each perpendicularly fastened respectively via screws 34 to each of the perpendicular end faces of a pair of long pillar members 32, 32' uprightly arranged and set opposite to each other in front of the column 14. Left and right pairs of slide dowels 38, 38' placed a

predetermined space apart in the rear of the main spindle head 18 are slidably engaged with the guide rails 36, 36' to ensure the stable vertical elevation of the main spindle head 18.

A support plate 39 is horizontally stretched between the tops of the pair of long pillar members 32, 32' and fixed thereto with bolts. An AC servomotor 40 containing a rotary encoder 42 is uprightly arranged on the support plate 39. A ball screw 44 is fastened to the end of the vertical rotary shaft of the servomotor 40 through a coupling 41, 43 and, as can be appreciated from Figure 4, the ball screw 44 is perpendicularly downwardly extended between the pair of guide rails 36, 36'. As shown in Figure 2, a nut 46 is horizontally fixed through a bolt 48 to a back projected portion of the main spindle head 18, the ball screw 44 being passed through and engaged with the nut 46.

When the AC servomotor 40 is activated, the ball screw 44 is rotated in the predetermined direction to cause linear movement without backlash to the nut 46, also causing the main spindle head 18 to be perpendicularly freely moved relative to the frame to the extent of a predetermined stroke. That is, the AC servomotor 40, the ball screw 44 and the nut 46 engaged therewith constitute a reciprocal driving mechanism for the main spindle head 18. The vertical stroke of the main spindle head 18, is, as discussed later and shown in Figure 3, roughly divided into (1) a machining region A for causing the workpiece to be machined by making a normal repetitive vertical movement and (2) an automatic tool changing region B, which is located above the region A, for allowing the tool 20 to be attached to, and be detached from, the main spindle 26 through a "double action" operation.

During the aforesaid "double action" operation which is carried out within the automatic tool changing region,

the main spindle head 18 undergoes a single reciprocation wherein a used tool is extracted from the main spindle 26 and a new or different tool is loaded. As will be more fully described later, there exist three elevational points within tool changing region B at which specific tool changing actions are initiated or completed. As a matter of course, the main spindle head 18 shown in Figures 1-3 is elevated up to the upper limit of the machining region A (or the lower limit of the automatic tool changing region B) upon completion of machining required for the workpiece, and remains in this so-called fixed or standby position until the next machining or tool changing instructions are given.

As shown in Figure 2, the hollow cylindrical main spindle 26 is inserted into a bearing 50 and is rotatably supported thereby to project under the main spindle head 18. The main spindle 26 has the tool mount 52 at its lower end, and its upper end is connected to a motor 56 uprightly arranged on top of the main spindle head 18 via output shaft 60 of a reducer 58 through a coupling 54.

As shown in Figure 2, the tool mount 52 is designed to mount the detachable tool 20 equipped with an arbor 62 having a tapered shank, by means of a conical opening for admitting the arbor 62. A pull stud 64 is provided at the rear end of the arbor 62 of the tool 20. The tool 20 is attached to the main spindle 26 by engaging the pull stud 64 with the tool holding member 66 which is slidably inserted in the hollow main spindle 26. The tool holding member 66 is formed with a known collet so arranged as to encircle the neck of the pull stud 64 with a plurality of balls 68, and to clamp and release the pull stud 64 as the tool holding member 66 slides in the hollow portion of the main spindle 26.

As shown in Figure 2, an annular plug 70 is vertically slidably inserted up to a predetermined height

in the hollow of the main spindle 26, and the upper end of a draw bar 76 is inserted in the vertical hole in the plug 70, fixed thereto, and extends downward along the central axis of the main spindle 26. The lower end of the draw bar 76 is connected to the top of the tool holding member 66. Oblong slots 74 (only one being shown) opposite to each other are made in the main spindle at the position of the plug 70 and both ends of a pin 72 perpendicularly inserted in the plug 70 extend horizontally outside the main spindle 26 through the pair of slots 74.

As shown in Figure 2, a group of compressed conical springs 78 is inserted in between a step formed in the lower hollow portion of the main spindle 26 and a washer 80 provided at the lower end of the plug 70. The tool 20 is mounted on the tool mount 52, and the draw bar 76 is located in the central portion formed by the group of conical springs 78. The force of the conical springs 78 is used to press the plug 70 upward and hold it at the predetermined position, whereupon the tool holding member 66 is resiliently drawn up to ensure that it holds the pull stud 64. A forked portion 81 formed at the tip of the second crank 30 (to be described in more detail later) is, when in a non-contact state, positioned close to the upper portion of the perpendicular cross pin 72 extending outwardly from the main spindle as shown in Figures 2, 4 and 10. This arrangement allows the draw bar 76 to be lowered by pressing the pin 72 as the crank 30 operates. That is, the cooperative operation of the second cam-and-crank mechanism 188, 30 causes the perpendicular cross pin 72 to be forced downwardly, and the draw bar 76 to be moved accordingly. Draw bar 76, in turn, lowers the tool holding member 66 and releases the pull stud 64 from the applied pressure derived from the balls 68, thereby releasing tool 20 from the tool mount

52. The reference character 83 in Figure 2 designates a cutting tool such as a drill bit or tap detachably connected to the tool 20.

The tool support 24, which is supported by the frame 16 in such a manner that it is movable in the axial direction independently of the main spindle 26, will now be described in more detail. In Figure 4, support plates 82, 82' are horizontally attached to a pair of opposite side walls 16a, 16a' constituting the frame 16. A pair of round guide rails 84, 84' are vertically fixed to the tool support 24 (in a manner to be described later), and are slidably inserted in a perpendicular throughhole suitably made in each of the respective horizontal support plates 82, 82'. A pair of horizontal left and right support plates 86, 86' similarly extend from the lower part of the frame 16, and the guide rails 84, 84' are slidably inserted in perpendicular holes in each of said horizontal support plates 86, 86'. The upper ends of each of the guide rails 84, 84' are respectively fixed to a support plate 91 installed on a top plate 88 horizontally bridged over the top of the tool support 24, and their lower ends to a support plate 89 installed on the bottom of the support plate 91.

Accordingly, the tool support 24 can be elevated to certain heights in region B relative to the frame 16 by sliding the guide rails 84, 84' through the respective pairs of horizontal support plates 82, 86 and 82', 86' as the first cam-and-crank mechanism 162, 28 is caused to operate during the "double action" movement of the main spindle head 18. A pair of stopper bolts 90, 90' is fitted in the support plate 91 installed on top of the tool support 24. The height of the stopper bolts is adjustable so that the tool support 24 can be held at a position having a predetermined height relative to the

frame 16 when the stopper bolts are kept stationary in the plane of the horizontal support plates 82, 82'.

The tool magazine 22 which holds many tools 20 radially arranged and which is capable of rotatably indexing them, is supported by the tool support 24. A supporting shaft 92 having an axis diagonally downwardly inclined at a predetermined angle relative to the horizontal plane is projected from, and fixed to, the tool support 24. The tool magazine 22 is rotatably supported by the supporting shaft 92 through a bearing 94. As shown in Figures 2 and 5, the tool magazine 22 is a disc formed with a large diameter flat toothed wheel 98 and provided with a plurality of radially extending tool holders 96 circumferentially arranged on the outer periphery thereof. The large diameter flat wheel 98 is fixed to the bearing 94 through a bolt 100 and engaged with a pinion 106 fastened to the rotary shaft 104 of a motor 102. Motor 102 is fixed to the tool support 24. The flat wheel 98 is rotated by the motor 102 through the pinion 106 to rotate the tool magazine 22 and index a required tool 20.

As shown in Figure 2, hollow cylindrical members 108 are arranged in suitable places on the tool support 24 so that their axial lines are in parallel with that of the supporting shaft 92. A compressed spring 110 resiliently contained in each of the cylindrical members 108 presses individual balls 112 against the flat wheel 98. On the flat face of the wheel 98 are provided recessed notches 114 at predetermined intervals in the circumferential direction and, by resiliently seating the balls 112 in the notches 114, the tool 20 can be click-stopped in position while a desired tool 20 is indexed.

As shown in Figures 2 and 5, a fork member 116 extended in the direction perpendicular to the central axis of the supporting shaft 92 is clamped and fixed to

the tip of the supporting shaft 92 through a bolt 118. A support plate 120 having a predetermined thickness is bridged over the lower side space between the forked portions of the fork member 116, and a pair of optical sensors comprising light emitting and receiving elements with their optical axes being aligned are oppositely arranged on a pair of fitting plates 122, 122'. As shown, plates 122, 122' are installed in parallel with each other and placed a thickness of the support plate 120 apart on the upper and lower faces of the support plate. A slit disc 126 rotating in combination with the tool magazine 22, and being fixed to the bearing 94, is placed in a non-contact state between the light emitting and receiving elements. Disc 126 which can pass across the light emitting and receiving elements and selectively block or unblock the light, together with the emitting and receiving elements constitutes an optical sensor 124 by which instructions can be given to an electric control circuit (not shown).

The tool holder 96 arranged on the outer periphery of the tool magazine 22 will now be described. The tool holder 96 is, as shown in Figure 6, composed of a pair of claw members 128, 128' mounted by a finger 130 to enable the claw members to simultaneously open and close. As shown in Figure 2, a plurality of fingers 130 are fixed by bolts 132 in the peripheral direction of the flat wheel 98 forming the base of the tool magazine at a predetermined central angle, and extend in the radial direction. Each finger 130 is formed with a plate member bent at a predetermined angle, and the respective pair of claw members 128, 128' (Figure 6) bent in a doglegged shape are positioned a predetermined space apart on the finger 130 to be rotatable through a predetermined angle about respective pins 134, 134'. A tension spring 136 is resiliently stretched over both the members. The claw

portions of the claw members 128, 128' facing each other are activated by the crank mechanism (in a manner to be described later) and caused to open and close, whereby a grooved flange 196 formed in the tool 20 can be gripped or released. As shown in Figure 6, the other ends of the pair of dog-leg-shaped claw members 128, 128' are connected via a shaft pin 138, which projects slightly from the rear side of the finger 130. When the shaft pin 138 in Figure 6 is urged in the Y direction, each of claw members 128, 128' closes and holds grooved flange 196 of the tool 20. On the other hand, if the shaft pin 138 is urged in the X direction, each of claw members 128, 128' will be rotated outwardly, releasing the tool 20 (shown by dashed lines in Figure 6). The angle (relative to the wheel 98) of the finger 130, each supporting one of the tool holders 96 on the outer periphery of the tool magazine 22, is set in such a manner as to make the axis of the held tool 20 coincide with the axis of the main spindle 26 when the tool 20 held by the tool holder 96 arrives at the lower side of the tool mount 52 provided at the toe of the main spindle 26, that is, when wheel 98 is rotatably indexed about shaft 92.

The mechanism for opening and closing the tool holder 96 will now be described. As shown in Figure 2, a crevice 140 is formed en bloc in the lower face portion of the support plate 89 (to which the lower ends of the guide rails 84, 84' have been fixed) provided in the tool support 24. A bell crank 142 having a desired shape is rotatably pivotally attached to plate 89 at the crevice 140 through a pin 144. A fork 146 is formed in the lower end of the bell crank 142, with the fork located at the position where the tool holder 96 arrives at the lower side of the main spindle 26 after the rotation of the tool magazine 22. The shaft pin 138 for selectively

driving the claw members 128, 128' to open or close is set in between the legs of the fork 146.

A vertical plate 148 shown in Figures 2 and 4 is fixed to the upper and lower horizontal support plates 82, 86, 82', 86' all attached to the frame 16, and a cam 152 (provided with a bent groove 150 of a predetermined shape) is attached to the front face of the vertical plate 148 through a bolt 154, as shown in Figure 3. A follower pin 156 is attached to the upper end of the bell crank 142 and is slidably inserted in the bent groove 150 of the grooved cam 152. The bell crank 142 pivotally attached to the tool support 24 is caused to elevate en bloc when the tool support 24 is elevated by the first cam-and-crank mechanism 162, 28 (to be described later). The pin 156 attached to the upper end of the bell crank 142 follows the bent groove 150 of the grooved cam 152 fixed to the frame 16, and the bell crank 142 turns slightly clockwise around the pin 144. The fork 146 of the bell crank 142 thus drives the shaft pin 138 of the tool holder 96 in the direction of the arrow Y of Figure 6 to close the pair of the claw members 128, 128'. If the bell crank 142 turns counterclockwise, the fork 146 drives the shaft pin 138 of the tool holder 96 in the direction of the arrow X and operates to open the pair of claw members 128, 128'.

There will now be described a mechanism for elevating the tool support 24 relative to the frame 16 in the automatic tool changing region to achieve the "double action" movement of the main spindle head 18. As shown in Figures 2-4, the first crank 28, 28' (having an L-shape as clearly shown in Figure 3) is rotatably pivotally attached to each of the internal faces of the opposite side walls 16a, 16a' of the frame 16 through shafts 158, 158'. As shown in Figure 4, the pair of first cranks 28, 28' are arranged in the interior of the

side walls 16a, 16a' respectively in opposed relation. Referring to Figure 3, a roller 160 is rotatably installed at the end of short arm 167 of crank 28. Similar components are associated with crank 28' but are not shown in Figure 3.

With continued reference to Figure 3, a first plate cam 162 having a tilted cam face 164 is attached to the side face of the main spindle head 18 through bolts 166. The first plate cam 162 is installed a predetermined space apart from, and under, the roller 160 rotatably attached to the first crank 28 to locate the main spindle head 18 at the upper limit of the automatic tool changing region B. A contact 170 is fixed to the upper end face of the long arm 168 of first crank 28. As shown in Figure 3, contact 170 is slightly separated from the lower end of a bolt 172 screwed into the support plate 91 fixed to the top plate 88 formed in the tool support 24 en bloc. Similar components are associated with a first plate cam 162' shown in Figure 4.

Referring again to Figure 3, when the main spindle head 18 is elevated by turning the servomotor 40 (to be described later), the roller 160 of the first crank 28 abuts the tilted cam face of the plate cam 162 attached to each of the side faces of the main spindle head 18 and turns the respective crank 28 clockwise around its axis 158. The contact 170 of the long arm 168 then abuts the lower end of the bolt 172 and elevates the tool support 24 along the guide rail 84 by the predetermined stroke. The dimensional ratio of the long arm 168 to the short arm 167 of the first crank 28 and the bent angle of both arms should be selected such that the elevated distance of the main spindle head 18 coincides with that of the tool support 24 elevated by the first cam-and-crank mechanism 162, 28 and such that their speeds are synchronized with each other.

A description will now be given of the second cam-and-crank mechanism, which second mechanism operates to make the tool holding member 66 provided in the tool mount 52 of the main spindle 26 release the tool 20 when the main spindle head 18 and the tool support 24 are moved in another part of the "double action" motion by the first cam-and-crank mechanism 162, 28. As shown in Figures 2 and 4, an L-shaped second crank 30 is installed in the main spindle head 18 to be pivotable through a predetermined rotating angle about shaft 176. A roller 180 is rotatably attached to the toe of the long arm 178 of second crank 30, whereas the toe of a short arm 182 is, as shown in Figures 4 and 10, formed as the forked portion 81 defining fork 184. The fork 184 encloses the main spindle, and is positioned slightly above the perpendicular cross pin 72 inserted in the plug 70 provided on top of the draw bar 76. Fork 184 is in a non-contact state when the machine tool is in the tool release instruction receiving mode. Although the main spindle 26 is rotated by the motor 56 during machining, the angular position of the rotary shaft of the motor 56 is controlled to always stop at a fixed position. Accordingly, the pin 72 which extends perpendicularly to the main spindle 26 is also caused to stop at the fixed position directly beneath the fork 184 shown in Figure 4, to ensure that the fork 184 engages pin 72 when the second crank 30 is operated.

A second plate cam 188 having a cam face with a predetermined inclination is arranged to cam the second crank 30 during elevational movement of the latter component when the main spindle head 18 is further elevated in the automatic tool changing region. In the apparatus shown in Figures 2 and 4, the second plate cam 188 is fixed to the perpendicular casing face of the rotary encoder 42 through bolt 190, and has a tilted cam

face 186 oriented perpendicularly downwardly. In operation, as the main spindle head 18 is further elevated, the roller 180 rotatably supported at the toe of the long arm 178 of the second crank 30 will be made to run on the tilted cam face 186 of the plate cam 188. As a result, the second crank 30 is turned counter-clockwise around the shaft 176 by a predetermined angle. The fork 184 provided at the toe of the short arm 182 contacts the perpendicular cross pin 72 and presses the pin 72 while forcing the draw bar 76 to drop a predetermined distance, thus lowering the tool holding member 66. Consequently, the balls attached thereto are released from the pull stud 64 and the tool 20 is also released from the tool mount 52. A laminated spring 192 is attached to the long arm of the second crank 30, and the released end of the laminated spring 192 contacts the upright end face of a horizontal support plate 194 provided on top of the main spindle head 18, whereby a clockwise return force is felt on the crank 30.

The operation of the first cam-and-crank mechanism 162, 28 always begins, during elevation of the main spindle head 18, prior to the operation of the second cam-and-crank mechanism 188, 30. As will be described in more detail later, when the main spindle head 18 is elevated (in this embodiment) a distance of about 20 mm from the basic position shown in Figure 2 (i.e. the lower limit position of the automatic tool changing position B), the first crank 28 is caused to contact the first plate cam 162 and elevate the tool support 24 a corresponding distance of 20mm. When the main spindle head 18 is elevated by a further distance of 30 mm, the second crank 30 abuts the second plate cam 188, pushes down the draw bar 76 through the cam action, and releases the pull stud 64 of the tool 20 from being held by the tool holding member 66.

Figures 8 and 9 show another tool holder 96" attached to the tool magazine 22, which tool holder is simpler in construction than that shown in Figure 6, so that the tool is more easily replaceable. The finger 130 arranged to radially extend at the predetermined central angle in the circumferential direction of the tool magazine 22 is provided with a fixed holding member 200 having an opening 198 wide enough to axially pass the large diameter flange 196 of the tool 20. When any particular tool holder 96", selected by indexing the tool magazine 22, arrives beneath the main spindle head 18, the centre of the opening 198 is aligned with the axis of the main spindle 26. Three horizontal step through-holes 202 spaced at angles of 120° are provided in the annular base of the tool holding member 200, and bar-like projections 204 having hemispherical ends are inserted in the step through-holes 202 to protrude into the opening 198. A compressed spring 206 is resiliently inserted in each of the through-holes 202 and the force of the spring 206 is made adjustable by turning a screw 208.

As shown in Figure 8, a V-shaped or crest groove 210 is provided in the periphery of the large diameter flange 196 of the tool 20 and, when the tool 20 is inserted in the opening 198 of the tool holding member 200, the hemispherical ends of the bar-like projections 204 forcefully engage the crest groove 210 to hold the tool 20. When the main spindle head 18 is placed at the fixed position as shown in Figure 8, the tool 20 mounted on the toe of the main spindle is held by the tool holder 96" through the aforementioned mechanism. Only when the main spindle head 18 is lowered (for a machining operation) below the standby position, is the crest groove 210 of the flange 196 engaging with the bar-like

projections 204 separated from the ends thereof and the tool 20 released.

The operation of the machine tool of Figures 1-6 and 10 will now be described. In Figure 2, after the main spindle head 18 completes normal cutting operation, it returns to the standby position and stops. At this point the main spindle 26 is in a position where the pin 72 crosses the short arm 182 of the second crank 30. If the next instructions are such that the cutting operation should be continued, the main spindle head 18 will enter the machining region A to machine the workpiece. If, however, the instructions relate to tool changing, the main spindle head 18 will undergo a "double action" movement and enter the automatic tool changing region B (to be described later). Referring now to Figure 2, because the shaft pin 138 of the tool holder 96 is pressed and held in the direction of X (Figure 6) by the fork 146 of the bell crank 142, the claw members 128, 128' are opened and the tool 20 is released. The crest groove 210 formed in the flange 196 of the tool 20 and held by the claw members 128, 128' is located lower than the claw members 128, 128' by a distance α and, without means for compensating for this offset, the tool 20 cannot be held at the fixed position even if both the claw members 128, 128' are closed. However, as the main spindle head 18 is elevated and while it moves from the position in Figure 2 to that shown in Figure 7(a), the first plate cam 162 moves and covers of distance of α until it abuts on the roller 160 installed on the first crank 28. This compensates for the crest groove 210 being positioned under the claw members 128, 128' by the distance of α.

When the instructions as to tool changing are given with the machine tool in the state as shown in Figure 2, the AC servomotor 40 is driven to turn the ball screw 44,

and the main spindle head 18 is vertically elevated up to the automatic tool changing region B. The main spindle head 18 undergoes the first stage of the "double action" as depicted in Figures 7(a) and 7(b). That is, the main spindle head 18 at the position shown in Figure 7(a) has been independently elevated by the distance α for reasons explained previously. The first plate cam 162 is then caused to abut on the roller 160 of the first crank 28. The contact 170 installed on the long arm 168 of the crank 28 then engages the lower end of the bolt 172 provided on the support plate 91 of the tool support 24. At this time, the AC servomotor 40 is controlled to rotate at a very low speed in order to reduce the noise generated by the contact 170 touching the bolt 172, after which time the AC motor 40 operates at the predetermined speed.

As shown in Figure 7(b), the main spindle head 18 is elevated a distance of, for instance, 20mm. During the elevation from Figure 7(a) to Figure 7(b) the first crank 28 is further turned because of the cam operation associated with the first plate cam 162 and caused to elevate the tool support 24 slidably supported by the frame 16 through the guide rails 84, 84', together with the main spindle head 18, through essentially the same distance, in this case 20mm. As the tool support 24 is elevated the bell crank 142 pivotally attached to the lower end thereof follows the bent groove 150 of the groove cam 152. Accordingly, the bell crank 142 then drives the shaft pin 138 of the tool holder 96 in the direction of the arrow Y of Figure 6, closing the pair of claw members 128, 128' to grip flange 196 of the tool 20.

The main spindle head 18 then undergoes the second stage of the "double action" motion to the position shown in Figure 7(c). During this second stage, because the roller 160 of the first crank 28 abuts tilted cam face

164 of the first plate cam 162, the tool support 24 together with the main spindle head 18 is elevated a greater distance, for instance, 30mm in this case. As the main spindle head 18 undergoes the second stage of the "double action" motion, the roller 180 installed on the long arm 179 of the second crank abuts the second plate cam 188 located at the upper fixed position, causing crank 30 to be turned counterclockwise around the shaft 176. The fork 184 provided at the end of the short arm 182 then contacts and depresses the perpendicular cross pin 72. As a result, the balls are released from the pull stud 64 of the tool 20, which is thus released from the tool mount 52 at the toe of the main spindle 26. As mentioned previously, the tool 20 is still held by the tool holder 96 installed on the tool magazine and therefore the released tool 20 is prevented from dropping. Although the bell crank 142 attached to the tool support 24 is elevated relative to the groove cam 152 fixed to the frame 16, the bell crank does not undergo a camming operation because the follower pin 156 has already passed the tilted portion of the bent groove 150 and is located in a groove portion which is in parallel with the axis of the main spindle 26.

The main spindle head 18 subsequently undergoes the third stage of the "double action" motion of the present invention to the position shown in Figure 7(d). In the third stage, spindle head 18 is elevated a still greater distance, for instance, 70mm in the present case. At this time, because the roller 160 of the first crank 28 engages the flat face of the first plate cam 162, no camming action occurs and, accordingly, only the main spindle head 18 is allowed to be elevated, and the tool support 24 is not elevated. The roller 180 of the second crank 30 runs on the flat face of the plate cam 188, resulting in no camming action of crank 30, and the draw

bar 76 is kept pressed down to maintain the pull stud 64 in a release mode. As mentioned above, because the tool 20 is being held by the tool holder 96, the arbor 62 of the tool 20 is pulled out of the tool mount 52 at the toe of the main spindle 26 as the main spindle head 18 is elevated relative to tool support 24. The main spindle head 18 is moved up above the top of the pull stud 64 of the tool 20 held by the tool holder 96 and is stopped thereat, completing the third stage.

Subsequently, the motor 102 in the tool magazine 22 rotatably indexes the extracted tool 20 away from the tool mount, causing a new or different tool to arrive at the position under the tool mount 52 and stop in axial alignment with the main spindle 26. Then the above-described operations depicted in Figures 7(a)-7(d) are repeated, but in reverse order, to complete the "double action" and to replace the tool automatically. That is, the main spindle head 18 is lowered by 70mm and the arbor 62 of the replacement tool is mounted on the tool mount 52. Spindle head 18 is then further lowered by 30mm to release the second crank 30 from pressing the draw bar 76, whereby the tool holding member 66 is caused to engage the pull stud 64 of the replacement tool under action of conical springs 78. As the main spindle head 18 and the tool support 24 subsequently are lowered by 20mm, the bell crank 142 operates in reverse to press the shaft pin 138 of the tool holder 96 in the direction of the arrow X of Figure 6 to open the claw members 128, 128', whereby the replacement tool is released from the tool support 24.

As set forth above, in the machine tool according to the present invention, the tool support for rotatably supporting the tool magazine is installed on the frame of the machine tool proper, isolated from the main spindle head but upwardly movable in the axial direction of the

main spindle only above a fixed axial location, that is, above the upper limit of the machining region A. The tool magazine is so arranged as to be supported at a fixed position on the frame when the main spindle is lowered to machine a workpiece in the machining region, so that tools mounted on the magazine cannot interfere with the workpiece. Moreover, since only vertical motion of the main spindle head in the automatic tool changing region is required for tool replacement, such a machine tool can be made simple in construction and offer many advantages.

CLAIM

A machine tool, for machining a workpiece, comprising:

a frame;

a main spindle having one end provided with a tool mount;

a main spindle head rotatably supporting said main spindle for rotation about the axis of said main spindle, said main spindle head being reciprocable relative to said frame in the axial direction of said main spindle; and

a tool magazine rotatably supported on said frame, said tool magazine being capable of indexing tools and having tool holding means including a plurality of tool holders spaced about an outer peripheral portion thereof, the axis of a tool held by the indexed tool holder being aligned with the axis of said main spindle, each of said tool holders comprising of pair of claw members which are supported for movement between a first position for holding said tool and a second position for releasing said tool, the claw members of the indexed tool holder being moved to said second position for allowing said main spindle head to pass between said claw members during machining of said workpiece.

Amendments to the claims have been filed as follows

1. A machine tool, for machining a workpiece, comprising:

a frame;

a main spindle having one end provided with a tool mount;

a main spindle head rotatably supporting said main spindle for rotation about the axis of said main spindle, said main spindle head being reciprocable relative to said frame in the axial direction of said main spindle; and

a tool magazine rotatably supported on said frame, said tool magazine being capable of indexing tools and having tool holding means including a plurality of tool holders spaced about an outer peripheral portion thereof, a selected one of the plurality of tool holders being indexable into a position in which the axis of a tool held by said selected tool holder is aligned with the axis of said main spindle;

each of said tool holders comprising at least a pair of claw members which are supported for movement between a first position for holding said tool and a second position for releasing said tool, the claw members of said selected tool holder being moved to said second position after having been indexed to said aligned position for allowing release of said tool, said main spindle head subsequently passing between said claw members during machining of said workpiece.

2. A machine tool according to claim 1, in which each of the tool holders has two of said claw members mounted for rotary movement between their said first and second positions.

3. A machine tool according to claim 1, in which each of the tool holders has three of said claw members mounted for reciprocatory movement between their said first and second positions.

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